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ABSTRACT

Engineers and scientists in the United States have always been among the nation's greatest assets. Their work has led to world leadership in scientific and technological innovation. Recent trends are disturbing. These is concern over the quality of science and technical education at the elementary, secondary, and college levels. High school students in the United States lag behind those of other industrialized nations according to several sources. At the doctorate level, half of all graduate students in science are foreign nationals. To be economically competitive at home and abroad, the United States must have scientists and engineers who can keep the nation at the forefront of technological development. Reported in this document are: (1) "Trends Affecting the Future Supply of Engineering Students"; (2) "Systemic Barriers to the Participation of Women and Minorities in Engineering"; (3) "What Works at the State and Local Level"; (4) "The Governor's Role"; and (5) a "State Action Agenda." Appendices include descriptions of various state initiatives, and a directory of the Women and Minorities in Engineering Project Advisory Committee. A list of 44 references is included. (CW)

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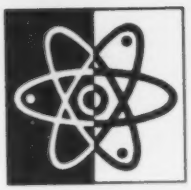

INCREASING THE SUPPLY OF WOMEN AND MINORITY ENGINEERS: AN AGENDA FOR STATE ACTION

NATIONAL GOVERNORS' ASSOCIATION

State Policy Reports

Capital Resources Policy Studies

Economic Development, Science and Technology Program

by Jean McDonald, Marianne K. Clarke, and Eric N. Dobson

Capital Resources Policy Studies
Center for Policy Research

National Governors' Association

The National Governors' Association, founded in 1908 as the National Governors' Conference, is the instrument through which the nation's Governors collectively influence the development and implementation of national policy and apply creative leadership to state issues. The association's members are the Governors of the fifty states, the commonwealths of the Northern Mariana Islands and Puerto Rico, and the territories of American Samoa, Guam, and the Virgin Islands. The association has seven standing committees on major issues: Agriculture and Rural Development; Economic Development and Technological Innovation; Energy and Environment; Human Resources; International Trade and Foreign Relations; Justice and Public Safety; and Transportation, Commerce, and Communications. Subcommittees and task forces that focus on principal concerns of the Governors operate within this framework.

The association works closely with the administration and Congress on state-federal policy issues through its offices in the Hall of the States in Washington, D.C. The association serves as a vehicle for sharing knowledge of innovative programs among the states and provides technical assistance and consultant services to Governors on a wide range of management and policy issues.

The Center for Policy Research is the research and development arm of NGA. The center is a vehicle for sharing knowledge about innovative state activities, exploring the impact of federal initiatives on state government, and providing technical assistance to states. The center works in a number of policy fields, including agriculture, economic development, education, environment, health, social services, training and employment, trade, and transportation.

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Preface

In 1989 the National Governors' Association (NGA) embarked on a study to identify short-term actions that could be taken by Governors to increase the number of women and minorities entering and completing engineering degree programs. The initiative was undertaken in concert with the National Science Foundation (NSF), which also provided financial support. Specifically, the project was designed to identify successful intervention strategies and to translate the lessons learned from these model approaches into a state action agenda.

Governors from the following states appointed representatives to serve on a Women and Minorities in Engineering Project Advisory Committee: California, Iowa, Michigan, Mississippi, New Mexico, New York, North Carolina, Ohio, and Texas. Members of the advisory committee are listed in Appendix B.

Four papers on exemplary programs were commissioned. These papers are contained in the recent NGA publication, *Realizing the Potential of Women and Minorities in Engineering: Four Perspectives from the Field*. Information on current state initiatives was collected and is contained in Appendix A.

This report analyzes the issues affecting the participation of women and minorities in science and engineering. It also presents recommendations for Governors, state agencies, and state educational institutions on how such participation can be increased.

Acknowledgements

The National Governors' Association wishes to thank the many individuals who contributed time and information for the development of this report. First and foremost, thanks are due to the state officials who served as members of the Women and Minorities in Engineering Project Advisory Committee.

Thanks also are due to Dale Draper and Sue Kemnitzer of the National Science Foundation for their input and support. Expert advice and guidance were provided by Raymond Landis, Dean of Engineering and Technology, California State University, Los Angeles; Jane Daniels, Director of the Women in Engineering Program at Purdue University; Paul Parker, Florida State Board of Community Colleges; and Minnie McGee, Assistant Dean, Ohio State University.

Finally, a number of NGA staff contributed to the effort. Barry Van Lare, Deputy Executive Director, carefully reviewed the draft report and provided valuable comments. Jean McDonald, Senior Policy Analyst in Education, conducted the background research and data analysis. Marianne K. Clarke, Program Director for Economic Development, Science and Technology, managed the project. Eric Dobson, Senior Staff Assistant with the Economic Development, Science and Technology Program, compiled the information on state initiatives. Karen Glass edited the report, and Raquel Stanton provided expert secretarial support. Their contributions are gratefully acknowledged.

Executive Summary

American engineers and scientists have always been among the nation's greatest assets; their work has led to world leadership in scientific and technological innovation. Recent trends are disturbing. There is concern over the quality of science and technical education at the elementary, secondary, and college levels. American high school students lag behind those of other industrialized countries, according to the National Assessment of Educational Progress' *The Science Report Card*. At the doctorate level, half of all graduate students in science are foreign nationals. To be economically competitive at home and abroad, the United States must have scientists and engineers who can keep the nation at the forefront of technological development. The supply of engineers is of particular concern because of the pivotal role they play in bringing new technologies to market.

The congressional Task Force on Women, Minorities, and the Handicapped in Science and Technology reports that by the year 2010, the United States could suffer a shortfall of as many as 560,000 science and engineering professionals. Shortages in personnel already have been felt in United States colleges and universities. The National Academy of Engineering reports that about 1,300 engineering faculty positions (or 8.8 percent of the total) were vacant in 1985. In addition, many of the scientists and engineers recruited in the 1950s in response to the launch of Sputnik are expected to retire in the early 1990s. The National Science Foundation projects that jobs for engineers in private industry will increase from 1.2 million in 1986 to almost 1.7 million in the year 2000.

Although enrollments in engineering increased from the mid-1970s to the mid-1980s, a number of trends indicate that the United States may have difficulty in meeting future demands for engineers. First, interest in pursuing an engineering degree has declined. In 1983 11.4 percent of all freshman students indicated an interest in majoring in engineering. By 1989 only 10 percent expressed such an interest. First-year engineering enrollments fell 17 percent between fall 1982 and fall 1989.

Second, the traditional pool of engineering students, which is overwhelmingly white males, is declining due to a number of demographic trends. These include a decline in the college-age population and an increase in the proportion of women and minorities in this population. Women constitute less than 4 percent of all engineers; blacks and other minorities also constitute less than 4 percent. Yet by the year 2010 one in every three eighteen-year-olds will be black or Hispanic, compared with one in five in 1985.

Figures on women and minority participation in engineering programs are disheartening. Black students receive 2.9 percent of undergraduate engineering degrees, while Hispanic students comprise 2.4 percent of engineering baccalaureates. Although female enrollments in engineering increased from 3 percent to 16 percent between 1975 and 1985, total female enrollments now are declining.

The third factor that will affect the nation's ability to meet future engineering personnel needs is students' ability to complete engineering programs. A strong

fundamental base in mathematics and science is a prerequisite to pursuing an engineering degree. Many students enter college without the necessary math and science skills. Changes must occur at the precollege level to ensure a supply of students with the necessary skills to complete a rigorous engineering curriculum.

To meet the need for engineering personnel, it will be necessary to better prepare all students in math and science, to attract more students into engineering, especially women and underrepresented minorities (blacks, Hispanics, and Native Americans), and to assist women and minorities who enter engineering to complete their degrees.

Intervention Strategies

Programs to encourage women and minorities to pursue and complete engineering degrees have been in place since the 1970s. In 1973 the National Academy of Engineering sponsored a symposium that kicked off the national minority engineering effort. A network of regional precollege programs to improve the math and science preparation of minority youth was established. Engineering colleges set up minority engineering programs to improve the academic performance and graduation rates of minority engineering students. Engineering colleges also established recruitment and retention programs for women in engineering. Much can be learned from these successful models regarding the barriers that prevent minorities and women from completing degrees in engineering and ways to overcome these barriers.

Precollege Programs. One of the major reasons underrepresented groups do not major in engineering is that they lack the necessary academic preparation and achievement. Poor academic preparation results from a variety of factors, including weak science and math curriculums in elementary and secondary schools, teachers ill-equipped to teach math and science, and a lack of course options and laboratory equipment in inner-city and rural schools. Low expectations of these students' performance held by their parents and teachers often are a self-fulfilling prophecy.

This problem is compounded when children are placed in classrooms or are assigned to teachers based on ability at an early age. For example, as early as middle school, a substantial number of minority students are placed in or choose non-academic tracks that make them ineligible for higher mathematics and science courses. Female students often are discouraged from high achievement in math and science and from pursuing male-dominated careers such as engineering.

Changes in curriculum and evaluation methods are needed to remove the artificial filters that deny students access to a quality education in science and mathematics. The filters must be replaced with pumps (i.e., programs and well-prepared teachers that promote and support the learning of mathematics and science for all students).

To successfully remove barriers to the participation of women and minorities in science and math, intervention must begin early, starting in elementary school. Parents must be involved, and positive role models must be provided. Supplementary activities to promote an interest in and understanding of science, such as Saturday schools or summer camps, are useful components of a successful strategy to increase

the number of students in the pipeline. The most effective programs have a strong academic focus.

Programs to attract young women into math and science must offer support to counteract the social pressures that may discourage young girls from pursuing math- or science-related interests. They also must encourage young women to strive for greater achievement in mathematics and science. The attitudes of teachers and counselors can be particularly influential in encouraging or discouraging female students to pursue math and science interests.

Undergraduate Programs. High dropout rates, lack of preparation, and the failure of able students to enroll in college, in part due to financial constraints, limit the number of minority students entering college. In addition, a large percentage of minorities who attend college enroll at community colleges that do not offer engineering courses. Even if the two-year college offers the prerequisite courses, transferring credit to a four-year engineering college often is difficult.

Minority students who enroll in engineering colleges face a number of barriers, including a lack of role models, lack of appropriate support services, and low faculty expectations. The engineering college environment is geared toward white males, and despite recent attempts to establish special programs for underrepresented groups, women and minorities may feel isolated and lack peer support.

Fewer than one-third of the universities with accredited undergraduate engineering programs have formal minority engineering programs; about one-third have women in engineering programs. The most effective programs focus on shaping women and minority students into an academic community and promoting a high level of collaborative learning.

Equally important are efforts to train faculty to be effective as academic advisers, mentors, and teachers of women and minority students. While existing approaches to fostering such behavior have been replicated, implementation has not been widespread.

The Governor's Role

Over the past five years, the nation's Governors have waged an aggressive campaign to improve the nation's education system. In February 1990 they adopted a set of national education goals that includes the goal of being first in the world in math and science achievement by the year 2000. Within their own states, Governors have promoted programs to require additional teacher training in basic science and mathematics, and have established highly competitive scientific secondary schools. They also have stressed more performance measurement, greater accountability, and more parental choice.

Governors can play a leadership role in encouraging the participation of women and minorities not only in engineering, but also in scientific and technical fields generally. Specifically, Governors can:

- Support education reform aimed at improving K-12 math and science education for all students.

- Provide programs targeted to women and underrepresented minorities.
- Work with the private sector to increase awareness among parents, teachers, counselors, and students of opportunities in math and science and of the importance of math and science to the future competitiveness of U.S. businesses.
- Serve as advocates for the establishment and expansion of programs that encourage more women and minorities to pursue careers in science and engineering.
- Encourage colleges of engineering to implement minorities and women in engineering programs through funding decisions and incentives.
- Provide incentives to engineering schools that reward faculty for activities enhancing the educational experience of women and minority students.
- Form a statewide cooperative effort to link organizations and individuals involved in efforts to increase the numbers of women and minorities who receive the education, encouragement, and financial support they need to pursue a career in science or engineering.
- Support the involvement of women and minorities in state science and technology programs.

State Action Agenda

State agencies and state education institutions can undertake a variety of activities at the precollege, undergraduate, and graduate levels to make students aware of opportunities in science and engineering, to prepare women and minorities to pursue advanced engineering degrees, and to improve graduation rates for women and minorities in engineering. A successful intervention strategy should incorporate the following objectives.

Improve the study of mathematics and science in grades K-12 for all students, and provide programs targeted to women and underrepresented minorities. Any effort to increase the number of students entering engineering programs will depend on the ability of the public school system to provide students with a strong foundation in basic mathematics and science. States should:

- Improve math and science teaching at the elementary and secondary levels by creating incentives to attract teachers to these subject areas, strengthening teacher preparation in both content and practical experience, and offering continuing professional development and support in these subjects.
- Support programs designed to interest young women and minorities in math, science, and engineering, and to prepare them to enter college.
- Eliminate the tracking of students by ability to ensure that all students are taught advanced math and science skills.

- Allow alternative certification to enable practicing or retired scientists and engineers to teach math and science at the K-12 level.
- Provide incentives to promote collaboration among elementary and secondary schools and engineering, mathematics, and science faculty.

Improve the ability of students to transfer from two-year community colleges to engineering programs. About half of the women and minority students enrolled in college attend community colleges. If underrepresented groups are to be recruited or prepared to enroll in colleges of engineering, steps must be taken to facilitate the flow of students from community colleges to such colleges. To achieve this goal states should:

- Promote strengthened articulation (i.e., coordination of educational institutions to ensure that students are able to transfer credits) between two-year and four-year schools by developing transfer agreements and dual admission programs.
- Establish a statewide articulation coordinating committee to encourage programmatic articulation, monitor agreements, and adjudicate conflicts.
- Encourage colleges and universities to appoint articulation officers or liaison persons to help recruit students from community colleges and to help alleviate adjustment problems of transfer students.
- Create incentives for universities to work with community colleges and/or public four-year colleges with large minority enrollments through exchange programs, campus visitations, and orientation programs for transfer students.
- Encourage community colleges to strengthen their math and science programs to be more compatible with those of four-year schools.

Promote the development of undergraduate minority engineering programs to improve the academic performance and graduation rates of minority engineering students. Of the 270 universities in the United States with accredited undergraduate engineering programs, it is estimated that fewer than 100 have established programs to improve the academic performance and retention of minority students. These programs differ in level of effort and effectiveness. Much is known about the elements of programs that help students succeed. States should:

- Create challenge or incentive grants to encourage colleges of engineering and departments of mathematics and the sciences to develop recruitment and retention programs.
- Reward effective programs and encourage their replication.
- Encourage colleges of engineering and departments of mathematics and the sciences to engage in partnerships with the private sector. Seed money or incentives may be needed to initiate such efforts.
- Provide increased financial aid to minority engineering students so they will not be required to work excessively and can devote their full-time effort to engineering study.

Encourage the establishment and expansion of programs that specifically encourage more women to pursue careers in engineering. Women comprise about half of the population of every state in the nation. They are the most underrepresented, but also the most accessible, human resource available to meet the projected shortages of engineering talent for the future. To better utilize this resource, states should:

- Initiate or increase financial support to existing women in engineering programs at state colleges and universities, and offer incentives to industries to support these programs.
- Reward effective programs and encourage their replication.
- Develop state scholarship programs to encourage young women to choose engineering as a major.
- Encourage state colleges and universities to use multiple admission criteria in addition to standardized test scores. The use of standardized test scores, especially math scores, eliminates large numbers of women from the pool of potential engineering students.

Develop programs to improve faculty awareness of the needs of women and minority students at both the college and precollege level. Faculty have a key role to play in increasing the number and proportion of women and minority engineering students. Engineering faculty, the vast majority of whom are white males and increasingly foreign-born, may not be sensitive to the problems experienced by female and minority students. States should:

- Provide funding to train engineering faculty to be effective in their roles as academic advisers, mentors, and teachers of women and minority students, and to have higher expectations of these students.
- Support statewide implementation of programs aimed at educational equity, including training to help elementary and secondary teachers understand the cultural and sex-biased expectations they bring to the classroom.
- Provide incentives for universities to reward faculty for activities, such as mentoring and advising, that enhance the educational experience of women and minority students.
- Provide incentives for engineering schools to increase the representation of minorities on their faculty.
- Fund a program to support substantial loans to resident women and minority graduate students to pursue doctoral degrees in the sciences and engineering, with a forgiveness clause for faculty service at an in-state institution.

Hold schools and colleges and universities accountable for increasing the number of women and minority students who complete engineering degrees. In their efforts to encourage widespread application of proven approaches, states should:

- Collect enrollment and graduation data on groups of students who are involved in precollege or undergraduate programs as well as for all stu-

dents. This information can be used to help inform policy and to identify effective intervention approaches.

- Encourage the Accreditation Board of Engineering and Technology (ABET) to consider a college's success in enrolling and graduating women and minorities when the agency grants college of engineering accreditation.

Incorporate the goal of increasing the number of women and minority engineers into state science and technology programs. States have built an impressive track record in technology development and commercialization. State support for applied research and the establishment of advanced technology centers is encouraging more market-driven research and influencing university researchers. Such programs provide opportunities for student participation. States should:

- Require state-funded advanced technology centers or centers of excellence to incorporate activities in support of women and minority engineering students.
- Provide incentives to encourage the participation of women and minorities in state-funded research projects.
- Include women and minorities on public/private boards established to oversee state science and technology policy.

Conclusion

The current lack of women and minorities in science and engineering is a critical issue facing the nation. Since the 1970s policies and programs have been established to recruit and retain women and minorities in engineering degree programs. While a number of programs have proven highly successful, these efforts have been fragmented and implementation has not been widespread.

Changes are needed at the K-12 level to ensure that all students receive high quality instruction in math and science. The current emphasis on improving math and science education provides an opportunity to incorporate into proposed education reform the goal of improving the participation of women and minorities. Governors have actively supported education reform. Addressing the special needs of women and minorities should be included in any strategy to achieve the goal of being first in the world in math and science achievement by the year 2000.

Although efforts to improve K-12 science and math education are necessary, this approach will not be sufficient. Universities must do a better job of retaining and graduating women and minority engineering students. Of those students who enter college well prepared in math and science, women and minorities are less likely to complete their degrees. Currently, only one in three minority students who begin the study of engineering ever graduates. Engineering colleges must recognize the specific needs of minorities and women and take steps to change the white-male-dominated culture that exists on most campuses. Engineering faculty and administrators should be held accountable for policies and attitudes that discourage women and minority students.

Governors can play a key leadership role in increasing awareness of the critical need to enable more women and minorities to pursue technical degrees. However, they will want to work in conjunction with school systems, colleges and universities, and the private sector. Working together, it will be possible to ensure that all students receive the education needed to meet the demands of the twenty-first century.

1. Introduction

American engineers and scientists have always been among the nation's greatest assets; their work has led to world leadership in scientific and technological innovation. That leadership is threatened by several trends. There is concern over the quality of science and technical education at the elementary, secondary, and college levels. American high school students lag behind those of other industrialized countries, according to the National Assessment of Educational Progress' *The Science Report Card*. At the doctorate level, half of all graduate students in science are foreign nationals. To be economically competitive at home and abroad, the United States must have scientists and engineers who can keep the nation at the forefront of technological development.

By the first decade of the twenty-first century, estimated shortfalls of scientists and engineers are as high as 560,000.[1] Relying on the traditional source of engineers—white males—will not allow the nation to maintain the status quo, much less meet anticipated shortfalls. To meet the nation's research and technology needs, substantially more women and underrepresented minorities, populations traditionally underutilized in science and engineering, must be trained in these fields.[2]

The urgent need to increase the supply of engineers is recognized in a number of recent reports by state and federal policymakers.[3] For example, in 1989 the National Governors' Association Task Force on Research and Technology recommended that states strengthen the effectiveness of business in the development of new products and of faster, more flexible manufacturing processes. An adequate supply of high-quality engineers is vital to the implementation of both recommendations. The task force pointed out that the United States lags behind its competitors in the proportion of scientists and engineers in the workforce. It also urged states to address the potential shortfall in engineers by boosting the number of women and minorities in science and engineering programs.[4]

In 1989 the National Governors' Association Center for Policy Research, with support from the National Science Foundation, embarked on a project aimed at identifying successful approaches to increasing the participation of women and minorities in engineering and developing a state action plan. This report presents the findings of the study. It begins with a description of the demographic trends that will affect the future supply of engineers. It then reviews systemic barriers to increased participation by women and minorities in the engineering profession. Next it examines effective state and local strategies for boosting the number of women and minority engineers. Finally, it proposes activities to be undertaken by Governors, state agen-

cies, and state educational institutions to increase the number of women and minorities entering and completing engineering programs.

2. Trends Affecting the Future Supply of Engineering Students

The potential pool of engineering students will be affected by several trends over the next two decades.

- The number of college-age students (i.e., persons between eighteen and twenty-four years of age) is decreasing.
- The proportion of white males, the traditional source of college engineering students, is decreasing.
- Females now make up more than one-half of the nation's college graduates, but only about 15 percent graduate with engineering degrees. Moreover, female interest in engineering has leveled off.
- The proportion of college-age black and Hispanic students enrolled in higher education has declined since the mid-1970s, but their enrollment in engineering programs has fluctuated and currently is rising.
- Black, Hispanic, and Native American students experience low retention rates in college in general, and in engineering programs in particular.
- After a decade of increased enrollment in engineering, today's students generally are less interested in majoring in engineering.

Declining College-Age Population

The college-age population has been decreasing since 1983, and that trend is reflected in lower engineering enrollments. First-year engineering enrollments fell 17 percent between fall 1982 and fall 1989.[5] The decrease in the college-age population is expected to continue through 1996, for a total 25 percent reduction between 1983 and 1996, at which time it is expected to level off until about 2005.[6] The decline has special implications for engineering because the primary source of engineering majors has been students between eighteen and twenty-four years of age.

Decreasing Proportion of White Male Students

Engineering students traditionally have been white and male. At present, this group represents about three-fourths of the graduates in natural sciences and engineering.[7] White males also have relatively high staying power. While it is difficult to measure retention rates without tracking individual students, persistence in an engineering program may be approximated by dividing the number of students in a graduating

class by the number of freshmen four years prior. Accordingly, about 70 percent of white male engineering freshmen ultimately receive bachelor's degrees.

The proportion of white males in the eighteen- to twenty-four-year-old age bracket is getting smaller due to higher birth rates and immigration rates among minorities. By 2025 minorities will comprise 40 percent of the college-age population.[8] The white male population will continue to decrease into the twenty-first century, and if past enrollment trends continue, the decline will affect the engineering supply.

Increasing Proportion of Female Students

Between 1970 and 1987 the number of women attending college increased by 93 percent. Women currently account for 54 percent of college attendees. Consequently, the female population is potentially one of the most fruitful sources of engineering majors. Between 1975 and 1985, it appeared that female engineering students would be the answer to the engineering shortfall, as the female enrollment rate in engineering programs rose from 3 percent to 16 percent. The number of women awarded engineering bachelor's degrees increased from 860 in 1975 to 11,203 in 1986, an increase of 1,203 percent (see Table 1).

Table 1
Number of Engineering Bachelor's Degrees Awarded by Gender, 1975 and 1986

Gender	*1975*	*1986*	*Percent Change*
Females	860	11,203	1,203%
Males	39,205	65,858	68%

SOURCE: National Science Foundation, *Women and Minorities in Science and Engineering* (Washington, D.C.: National Science Foundation, January 1988, pp. 198-99, and January 1990, pp. 134-35).

Female engineering students are more likely than male engineering students to be minorities and are less likely to be foreign-born. In 1985 women constituted 28 percent of black engineering graduates and 31 percent of Hispanic engineering graduates.[9] In contrast, only 14.5 percent of engineering baccalaureate degrees awarded to white students were earned by women.

Unfortunately, as enrollment rates for women engineering students increased, the rate at which freshman women appeared to persist through graduation dropped. In the early 1970s, 90 percent of the women who enrolled in engineering as freshmen graduated four years later; in the peak enrollment years, only 65 percent of freshman female engineering students received their bachelor's degrees in four years.[10]

The number of female engineering majors declined in the mid-1980s. Since male enrollment also is down, the proportion of females among engineering majors has remained steady at about 15 percent. Since freshman women currently show less interest in engineering careers, it is unlikely that this situation will reverse itself in the near future. Female students are currently flocking to business majors. The glamour of the engineering profession has lessened as the environmental effects of technologi-

cal "advances" become more visible. Moreover, generally higher unemployment rates, lower salaries, and inhospitable work environments for female scientists and engineers may discourage women from entering the engineering profession as compared with other fields.[11] Finally, the number of engineering college programs to recruit and retain female students declined in the 1980s.[12]

Decreasing Minority Enrollment

In recent years the proportion of minority students attending college has decreased significantly. This followed a period of rapid increases in the early 1970s.[13] For black students, the percentage of high school graduates enrolled in college topped at 34 percent in 1976 and decreased to 28 percent by 1988; Hispanics registered gains up to 36 percent, experiencing a drop to 31 percent by 1988 (see Table 2).[14] Native American enrollment has remained low; it is estimated that 17 percent of graduating students attend college.[15]

Table 2
College Participation by High School Graduates by Racial/Ethnic Group, 1968-1988

Year	*Whites*	*Blacks*	*Hispanics*
1968	35%	25%	NA
1972	32	27	26%
1976	33	34	36
1980	32	28	30
1984	34	27	30
1988	38	28	31

NOTE: NA means not available.

SOURCE: Deborah J. Carter and Reginald Wilson, *Minorities in Higher Education: Eighth Annual Status Report* (Washington, D.C.: American Council on Education, 1989), Table 1, p. 20.

As shown in Table 3, college enrollment figures for minorities between the ages of eighteen and twenty-four—the traditional college-age population—are even lower. Only 21 percent of blacks and 17 percent of Hispanics in this age group attended college in 1988. These percentages reflect a decrease in minority enrollment from the peak year of 1976.

The drop-off in the proportion of minority college-age students attending college has been most severe among males and low-income students. The only reason that the proportionate attendance rate for blacks has not demonstrated even greater decline is that black female attendance rates (41 percent in 1988) have made up for the lower black male attendance rates (30 percent in 1988). The decrease in college attendance has occurred at the same time that high school graduation rates for blacks have risen.

Table 3
College Participation by Eighteen- to Twenty-Four-Year-Olds, by Racial/Ethnic Group
1968-1988

Year	*Whites*	*Blacks*	*Hispanics*
1968	28%	14%	NA
1972	26	18	13%
1976	27	23	20
1980	26	19	16
1984	28	20	18
1988	31	21	17

NOTE: NA means not available.

SOURCE: Deborah J. Carter and Reginald Wilson, *Minorities in Higher Education: Eighth Annual Status Report* (Washington, D.C.: American Council on Education, 1989), Table 1, p. 20.

Increasing Numbers of Minority Engineering Students

Trends in minority engineering enrollment do not necessarily mirror developments in college enrollment. Minority enrollment in engineering programs began to increase substantially about the same time that overall college enrollment went down. Blacks increased from 2.8 percent of freshman engineering students in 1972 to 6 percent in 1979, and then held steady until 1988 when the proportion again began to increase. The percentage of Hispanics increased from about 3 percent in the 1975 freshman class to 4.6 percent in 1979, and then remained the same until 1988. Native Americans remained below .5 percent throughout this decade.

Black, Hispanic, and Native American students accounted for 55 percent of the increase in freshman engineering enrollment in 1988.[16] Minority student enrollments rose from 10,325 in fall 1987 to 11,754 in fall 1988, an increase of 13.8 percent. Black student enrollment in engineering increased by 15 percent, Hispanic enrollment by 11 percent, and Native American enrollment by 22.3 percent.[17] Graduation rates for minorities in the engineering classes of 1988 and 1989 also showed marked gains.[18] It remains to be seen whether this is a temporary phenomenon or marks the beginning of a long-term trend (see Table 4).

Continuing High Attrition Among Minority Students

College attrition rates are high for minority students in general, and for minority engineering students in particular. About one-third of black freshmen in engineering earn bachelor's degrees in that field in four years.[19] Hispanic engineering students are more likely than blacks to stay until graduation; about one-half receive their degrees. Persistence rates for the small number of Native American students who enroll in engineering programs are low; about one-third graduate with engineering degrees. The persistence rates for minority engineering freshmen contrast markedly with the rate for all engineering freshmen, 70 percent of whom receive engineering bachelor's degrees.[20]

Table 4
Number of Engineering and Engineering Technology Bachelor's Degrees Awarded by Racial/Ethnic Group, 1977 and 1987

Racial/Ethnic Group	*1977*	*1987*	*Percent Change*
Whites	42,072	71,866	71%
Blacks	1,385	3,420	147
Hispanics	1,290	3,187	147
Native Americans	135	283	110
Asians	1,211	6,378	427

NOTE: The engineering degrees for racial/ethnic groups include figures for engineering technologies majors.

SOURCE: National Science Foundation, *Women and Minorities in Science and Engineering* (Washington, D.C.: National Science Foundation, January 1990), pp. 136-37.

Declining Student Interest in Engineering

The period between 1975 and 1985 was an "engineering boom," when students were attracted to engineering in record numbers because of high starting salaries and good job opportunities. The number of engineering graduates during that period increased from 38,000 to more than 77,000. Since the mid-1980s, interest in engineering has waned. For example, 22.3 percent of freshman males in 1982 planned engineering careers; by 1986 this figure had dropped to 19.7 percent. Women students also are showing less interest in engineering. Of all fall 1989 freshmen, only 10 percent expected to major in engineering, compared with 11.4 percent in 1983.[21]

Conclusion

An attractive job market in the late 1970s and 1980s accelerated engineering enrollments, including enrollments from previously underrepresented groups. However, because they either transferred to other fields of study or dropped out of college altogether, many of these students did not graduate in engineering.

Beyond job market factors, a variety of precollege intervention programs targeted to women and minorities resulted in increased engineering enrollments. Changes in societal attitudes toward women and minorities also made it more acceptable for them to enter nontraditional careers. However, engineering enrollment trends of the last decade do not confirm that the gains among these groups will be permanent. Consequently, it is clear that intervention strategies to attract and retain women and minority students in engineering must continue.

3. Systemic Barriers to the Participation of Women and Minorities in Engineering

Throughout their lives and their formal education, women and underrepresented minorities face barriers to attaining an engineering degree. These include:

- Poor academic preparation. This results from several factors, including exposure to weak science and math curriculums in elementary and secondary schools, teachers ill-equipped to teach math and science, failure to enroll in advanced science and math classes, low expectations of these students' performance held by their parents and teachers, and a lack of course options and laboratory equipment in inner-city and rural schools.
- A socialization process that discourages female students from high achievement in math and science and from pursuing male-dominated careers such as engineering.
- High dropout rates among minorities, and the failure of able students to enroll in college, in part due to mounting college costs.
- Problems associated with community colleges—in which most college-attending minority students are concentrated—such as lack of articulation with engineering programs at four-year colleges/universities or research institutions.
- Inhospitable campus environments for minorities, including few role models, a sense of isolation, a lack of appropriate support services, and an increasing number of racial incidents.
- Attitudes and practices of engineering and nonengineering college faculty, including low expectations for minority students and a tendency to weed students out of prerequisite science and math courses. The current reward structure for faculty tenure and promotion rewards research more than teaching and discourages attention to undergraduate education.
- Isolation of women and minority students within engineering colleges, including a scarcity of role models and a lack of commitment by administrators and faculty to meeting their needs.

Lack of Preparation at the Precollege Level

One of the major reasons underrepresented groups do not major in engineering is that they lack the necessary academic preparation and achievement. Preparation and achievement are interdependent since the lack of preparation affects achievement, particularly on standardized tests. Even when minority students take the necessary

mathematics and science classes, they tend to earn lower grades than majority students.

Achievement Gap. A gap in the achievement between whites and minorities and between males and females in mathematics and science has characterized student test scores for nearly twenty years. Although the scores of black and Hispanic students on mathematics tests have been increasing, relative to whites, the differential remains large. For example, seventeen-year-old black and Hispanic youth score either below or on a par with thirteen-year-old white students on the National Assessment of Educational Progress science and math examinations. Overall, boys age thirteen and older outperform girls in all science and mathematics standardized examinations. (Preteenage females score on a par with males on the standardized mathematics examinations.)[22] The situation is even more troubling because American students, including top scorers in these subjects, rank near the bottom when compared with students from other industrialized nations.

Curriculum. There is a growing consensus that the science and mathematics curriculums in American schools are flawed. Although curricular deficiencies affect all children, as evidenced by student performance, the impact has been greatest on female and minority students. Recent reports from the American Association for the Advancement of Science, the National Center for Improving Science Education, the National Council of Teachers of Mathematics, the National Research Council, and the National Science Teachers' Association fault the science and mathematics curriculums. Mathematical curricula emphasize basic computational skills rather than problemsolving skills and conceptual understanding of the subject matter. Science is accorded little attention in elementary schools. At the secondary level, science and mathematics classes cover many topics superficially rather than covering any topics in depth. At all levels students are not actively engaged in acquiring and using knowledge in these fields.

Methods of instruction also are important; student learning is promoted when students gain hands-on experience with science and mathematics rather than listen to a teacher lecture on a topic. "Students simply do not retain for long what they learn by imitation from lectures, worksheets, or routine homework," according to *Everybody Counts*, a report by the National Research Council.[23] Science and mathematics instruction also must build on students' knowledge base so students have a context in which to learn. Moreover, instruction in the two areas must be linked. Experts recommend that mathematics be embedded in the science curriculum and that science be embedded in the mathematics curriculum.

Teacher Quality. Another explanation for the poor performance of American students in general, and for females and minorities in particular, is the quality of public school instruction in mathematics and science. The results of the National Assessment of Educational Progress tests demonstrate that teachers are teaching, and that children are learning, the basics. However, in areas in which the teachers are not comfortable—problemsolving and higher-order mathematics and science—students are not learning the material. Teachers are not comfortable because preparation programs for elementary and secondary teachers lack sufficient training in mathematics and science. Not only must the preparation of new teachers be revamped, but the existing teacher workforce also needs additional training and development in

mathematics and science. Professional development should be related to new curricular frameworks and instructional approaches. For teachers to assume the role of "consultant, moderator, and interlocutor, not just presenter and authority," they must experience new instructional practices.[24]

In addition, the quality of students attracted to mathematics and science education programs has declined. One explanation is that women with science and mathematical aptitude now have expanded career opportunities and are no longer relegated solely to the teaching profession. Many of the better mathematics and science teachers, both men and women, have left the education profession for higher-paying jobs in other fields. As states and institutions restructure teacher preparation curricula in the direction of more rigorous training, it is anticipated that the quality of science and math teachers will improve.

Tracking Practices. In many communities students are placed in classrooms or are assigned to teachers based on their ability. Minority children are far more likely to be enrolled in low-level classes in mathematics and science than are majority children. Research has demonstrated that teachers cover less material and have different patterns of teacher-pupil interaction in such classes. Teachers are more critical, offer less praise, and provide little encouragement to students on the lower track. "These differences, along with the differences in the quality and level of science experiences available in high- and low-track classrooms, undoubtedly enhance the learning opportunities of students in more advanced classes and diminish those of students attending predominantly minority schools."[25]

Advanced Math and Science Course Enrollments. Despite upgraded state high school graduation standards that require students to take more mathematics and science courses than in the past, a recent analysis of course-taking patterns reveals that many students opt for basic courses rather than advanced ones. For example, female students are less likely than males to take precalculus, calculus, and trigonometry instead of basic mathematics courses, and are less likely to take physics instead of advanced biology. Further, as early as middle school, a substantial number of minority students are placed in or choose nonacademic tracks that make them ineligible for higher mathematics and science courses. As a result, black females are the least likely to take the rigorous courses required for pre-engineering, and are the most likely to take other mathematics courses such as business math.[26]

If students are to enter and succeed in a college-level engineering program, they must complete advanced math and science courses in high school. One report refers to this as a gate that excludes most young people from engineering.[27] In addition, *Everybody Counts* argues that "like science, math filters students out of itself (and ultimately degrees and careers in math) before the students ever see what the subject is about." There are several reasons for female and minority students' low enrollment rates in such courses. These students have a record of poor achievement in mathematics and science, receive inadequate information and advice from high school teachers and counselors, are "tracked" into a vocational or general education program, lack clear career goals at an early age, have low expectations held of them by parents and teachers, and have a poor self-image.

Lack of Course Offerings. Some students do not even have the option of taking advanced mathematics and science classes. Such classes are not always offered in inner-city schools, in which minorities are concentrated, or in rural areas. According to researcher Linda Darling-Hammond, the chance of minority high schools offering advanced mathematics and science courses is one-fourth as great as in majority schools.[28] Experienced and certified math and science teachers are more likely to be attracted to suburban schools than inner-city and rural schools. In fact, schools with a high minority student population have difficulty recruiting and keeping experienced and qualified teachers.[29] Eventually it is hoped that distance learning technology may allow students in all high schools to receive advanced courses through interactive video presentations by highly trained professionals. While distance learning programs are available in some areas, their implementation is far from widespread.

Lack of Laboratory Equipment. An additional problem for inner-city and rural schools is the science facilities may be wholly inadequate.[30] Without proper and updated laboratory and computer equipment, students lack crucial exposure to "hands-on" science activities.

Socialization. Socialization may further constrain female students' interest in an engineering career. Differential treatment of males and females begins in elementary science and mathematics classes.[31] Females receive fewer experiences with science equipment and instruments. They also receive less encouragement than males in these subjects. These trends are upheld even in high-ability classes. Differential treatment may continue through high school. Females may lack hands-on experience with mechanical devices or automobile engines that males have because it is considered "unfeminine." In addition, engineering is still viewed by teachers, counselors, and parents as a profession for men. Only females who are "A" students are encouraged to take the necessary mathematics and science courses to prepare them to study engineering in college, whereas males who are "B" students may be advised to pursue this field.

Dropouts. Many minority students are not eligible to study engineering because they never complete high school. School dropout rates for black students have decreased dramatically, though they still are at 22 percent nationally and may reach 40 percent in the inner cities. Native American students have the highest dropout rate of any racial/ethnic group, about 35 percent. These students face economic, social, and cultural problems that substantially impact their achievement and attainment levels in mainstream American society. Hispanic students, many of whom face language barriers in addition to problems related to low income, have a dropout rate of 28 percent.[32]

Conclusion. Because of these and other factors, not enough female and minority students are getting into the science and mathematics pipeline that will allow them the choice of an engineering, mathematics, or science career when they enter college. However, for minority students, and to a lesser extent female students, who overcome all of the obstacles and are accepted into a college engineering program, the barriers to achievement continue. Some of these impediments are external to the engineering program and are problems the students bring with them to college; others are internal to the engineering program. An additional challenge is that a substantial proportion of minority college students attend a community or two-year college.

Type of College Attended

High dropout rates, lack of preparation, and the failure of able students to enroll in college, in part due to financial constraints, limit the number of minority students entering college. For those who attend college, the type of college attended will influence their ability to study engineering.

Community Colleges. Approximately 44 percent of American college students are enrolled in community colleges; of these, 45 percent are minority students.[33] Forty-two percent of black college attendees, 54 percent of Hispanic attendees, and 50 percent of female attendees are enrolled in two-year colleges.[34] In contrast, 36 percent of all white college students attend community colleges. If underrepresented groups are to be recruited and/or prepared to enroll in colleges of engineering, attention must be paid to community colleges.

There are a number of obstacles associated with community college attendance that may make the transition to a college of engineering difficult. Community college students may not be given the necessary guidance to encourage them to transfer to four-year colleges/universities or research institutions. According to a College Board report, the transfer rate—as high as 30 percent in the 1970s—currently is estimated at between 15 percent and 25 percent.[35] The report of the Task Force on Women, Minorities, and the Handicapped in Science and Technology recommended that transfer centers be established in two-year colleges and vocational schools to enhance the number of students who transfer to baccalaureate-granting institutions in engineering and science.[36] If a student transfers into a four-year institution's engineering program, he or she may find that courses do not transfer and must be made up or repeated. Articulation between two- and four-year colleges sometimes is problematic.

Critics state that the quality of community college science and mathematics curriculum and instruction may not adequately prepare students who want to transfer into engineering. Community colleges also lack up-to-date laboratory equipment and apparatus.[37] Moreover, there is not enough interaction between faculty at two-year institutions and faculty in colleges of engineering. In short, students who have the necessary prerequisites are more likely to succeed in engineering if they enter a baccalaureate program directly. Still, students who receive associate degrees in engineering or engineering technologies are a rich source of potential students to complete engineering programs in four-year institutions (see Table 5). In addition, community colleges may be able to attract nontraditional students interested in upgrading their skills or in pursuing a new field of study.

Private and Public Institutions. Through its analysis of the U.S. Department of Education's longitudinal study of high school students graduating in 1980, *High School & Beyond*, the National Science Foundation (NSF) found that engineering and natural science students who attend private colleges and universities are the most likely to graduate. These colleges also are most likely to retain minority students to degree completion. In contrast, public four-year colleges have the poorest record of retaining minority students in general, and in these fields in particular. Nonetheless, public four-year schools enroll a higher proportion of minority college students than do public research universities. Research universities are more successful at retention

Table 5
Engineering and Engineering Technologies
Associate Degrees Awarded, 1984-1985

Associate Degree	*Male*	*Female*	*Total*
Engineering	3,473	408	3,881
Engineering Technologies	54,888	5,063	59,951

NOTE: Engineering technologies include electrical, electro-mechanic, electronic, civil, computer, industrial, and mechanical technology.

SOURCE: U.S. Department of Education, Office of Educational Research and Improvement, *Digest of Education Statistics, 1988* (Washington, D.C.: U.S. Government Printing Office, 1988).

than public four-year colleges, but less so than private institutions. While the NSF report acknowledges that more research is needed on the linkage between type of college and persistence, it conjectures that "it is possible that the less selective nature of public colleges, their smaller resource expenditure per student, and a greater tendency towards negative feedback and poor self-image by students having initial difficulty in their studies have combined to discourage minority students from greater persistence in the NS&E [natural sciences and engineering] pipeline and from trying other fields."[38]

Historically Black Colleges and Universities and Women's Colleges. Schools that have the highest success rate with the preparation and graduation of black students are the historically black colleges and universities. One-third of all bachelor's degrees and one-half of the mathematics bachelor's degrees awarded to black students are awarded by such institutions. Only seven historically black colleges and universities offer at least one accredited engineering degree program, though in 1989 these schools granted 19 percent of the engineering bachelor's degrees awarded to black students.[39] Women's colleges also demonstrate substantial success in training female scientists. The supportive climates, high faculty expectations of students, the presence of role models, and a critical mass of "like" students are among the explanations for their success.

Lack of Campus Support for Minority Students

A minority college student is most likely a first-generation college attendee. This means that almost every element of campus life—from course schedule to grading procedure to enrollment—is unfamiliar. Unless well developed in high school, student study habits may be inadequate for college-level work. The normal problems faced by a first-time freshman are compounded for minority students who may feel especially isolated and alone in a majority college setting.

Other problems make the adjustment to campus life difficult for minority students. They may need to work in order to afford college, and holding a job can interfere with the intense study required for the pre-engineering curriculum. If they live at home, they may take refuge there and not develop the networks important to college success. Also, they may need help learning the financial aid system. In the Western Interstate Commission for Higher Education's *A Crucial Agenda*, Genevieve

M. Ramirez and Paul B. Thayer cite these and many other problems for minority students. They recommend involving parents, introducing students to ethnic and support groups as part of orientation, helping students with study skills and the use of the library, and helping students develop basic classroom survival skills, such as how to approach professors.[40] A 1987 study of black undergraduate students found that black students received lower grades, had little interaction with faculty, and perceived campuses as socially discriminatory. They generally were more dissatisfied with campus life than white students.[41] These findings suggest that many minority students need special assistance and support to guide them through their freshman experience and beyond. The problems are compounded when underprepared students face a rigorous course of study, such as engineering.

Inadequate Financial Resources

Dramatic increases in the cost of college have made access to college more problematic for minority students. In fact, the proportionate decline in black enrollment rates for college-age students has been attributed to a combination of rising college costs, relatively lower family incomes, and decreasing student grant aid.[42] Not surprisingly, minority students are more likely to attend community colleges. The costs are relatively low and living at home makes the financial aspect more manageable. According to a study by the College Board, between one-third and one-half of all undergraduates leave school with a debt burden. The heavy reliance on loans may be affecting student decisions about career options after graduation.[43] It also may influence decisions about whether students can afford to stay in college until graduation, particularly for a five-year program. Clearly, financial aid issues are an important consideration in state strategies to increase the number of underrepresented minorities in the engineering field.

Harassment

Unfortunately, minority students must contend with an additional problem. In the past few years racism has re-emerged on a number of college campuses; during the spring semester of 1988 alone, seventy-eight racial incidents were reported on college campuses.[44] These events contribute to a negative campus climate and are not conducive to minority student success. Interestingly, the American Council on Education's 1989 Campus Trends survey found that 80 percent of campus administrators perceived racial tensions as being low on their campus.[45] Sexual harassment also can pose aggravating and illegal barriers to the academic success of female students. Both types of harassment sully the academic environment and reinforce the subordinate role traditionally held by these groups. It is clear that campuses must go beyond financial aid and tutoring—and even academic assistance—to achieve equity at colleges and universities.

Beyond overt racism, subtle discrimination continues to be practiced on campuses. In "Improving the Academic Performance and Graduation Rates of Minority Engineering Students," Raymond Landis, Dean of Engineering and Technology at California State University, Los Angeles, provides examples of racism experienced by minority engineering students.[46] On numerous occasions black students have

revealed to Landis that white students are hesitant to work in laboratory groups with them, will not sit next to them in class, or engage in other discriminatory treatment that sends a message of racism.

Traditional Faculty Attitudes and Expectations

In a recent report, *Higher Education for Science and Engineering: A Background Paper*, the Office of Technology Assessment argues that the quality of engineering education is as important to the future of engineering in the United States as is the number of students who are graduating. Faculty are a key component of a quality program, yet 9 percent of the engineering faculty positions are currently unfilled.[47] Moreover, it is estimated that 22 percent of the current engineering faculty will reach retirement age over the next ten years, creating even more vacancies.[48] Given a projected shortfall in Ph.D. production and the competitiveness of industry for Ph.D.s, universities may have to rely more heavily on foreign-born Ph.D.s, hire more part-time and adjunct faculty, or face continuing vacancies.

Lack of Female and Minority Faculty. Because few women and underrepresented minorities currently serve on engineering faculties, women and minority students lack crucial faculty role models. The proportion of these groups in engineering Ph.D. programs does not bode well for future hirings. In 1988 American universities granted doctorates in engineering to 15 black American men, 37 Hispanic men, 174 American women, and 2,089 foreign nationals.[49] About 2 percent of engineering faculty members are women.[50] Because of the high salaries offered to entry-level engineers, most students find it more attractive to take a job after they graduate—especially if they have sizeable loans—than to pursue graduate studies.

According to Landis, engineering faculty are not always sensitive to the problems experienced by female and minority students. Faculty tend to stereotype these students, hold low expectations of them, and blame them for being "deficient." Because few faculty members are trained to be sensitive to the special needs of these students, they often lack the skills to interact with and advise female and minority students. Programs such as the Faculty Advisors for Minority Engineering Students (FAMES) in California and Gender/Ethnic Expectations and Student Achievement (GESA) in Iowa help teachers and faculty overcome stereotypes linked to race and gender, alter attitudes, and develop skills for working with such students.

Foreign-Born Faculty. While fewer U.S. students are attending graduate school, more foreign-born students are pursuing advanced study; more than one-half of the engineering graduate students are foreign-born. One result of this trend is that colleges and universities are hiring more foreign-born faculty members, who now comprise 50 percent of assistant professors in engineering under age thirty-five.[51] Foreign-born faculty members, many of whom may be accustomed to cultures in which women are supposed to hold traditional roles, are perceived as less accepting of women in the engineering field. Such attitudes exacerbate the problems women face in pursuing a male-dominated career.

Mathematics and Science Faculty. The traditional engineering curriculum in a comprehensive university requires students to take mathematics and science courses for their first two years of college. These courses have traditionally "filtered out"

Top Ten Producers of Bachelor's Degrees in Engineering, 1987-88

Blacks	
Howard University	113
North Carolina Agricultural & Technical University	90
Prairie View	78
Southern University	73
City College of New York	64
Georgia Institute of Technology	63
Tuskegee University	61
North Carolina State University at Raleigh	59
Northwestern University	41
Purdue University at West Lafayette	40
Hispanics	
University of Puerto Rico	533
University of Florida	71
Texas A&M University	68
Florida International University	68
University of Miami	64
University of Texas El Paso	58
California State University at Long Beach	57
New Mexico State University	56
Texas A&M University	50
University of Texas Austin	50
Total Engineering Degrees	
University of Illinois Champaign	1,353
Purdue University at West Lafayette	1,155
Texas A & M University	1,122
Pennsylvania State University	1,089
Georgia Institute of Technology	1,031
North Carolina State University at Raleigh	985
Ohio State University	869
Virginia Polytechnical Institute and State University	860
California State University at Long Beach	850
University of Michigan Ann Arbor	809

SOURCE: American Association of Engineering Societies, Engineering Manpower Commission, "Engineering Enrollment Highlights" (Washington, D.C.: American Association of Engineering Societies, fall 1989).

students with inadequate preparation or study skills; unfortunately, minorities are more likely to have such deficits. It has been acceptable for mathematics and science faculty and engineering faculty to expect high failure rates in classes such as calculus. However, the mathematics community is now talking about calculus as a means to success, rather than as a way to screen students out of more advanced courses. It will take time for faculty to change this traditional attitude toward introductory courses and to restructure courses and instruction in a manner that will promote achievement.

While these basic mathematics and science courses are extremely important in preparing engineering majors for their college careers, graduate assistants, rather than full professors, often teach these critical "gateway" classes. Because a substantial

proportion of the graduate assistants are foreign students, these classes may be taught by teachers for whom English is not their native language.

The Engineering College Environment

The engineering college environment is geared to white males, and despite recent attempts to establish special programs for underrepresented groups, women and minorities may feel isolated and lack peer support. In classrooms, minority or female students may hesitate to speak out in a situation in which they are decidedly outnumbered by white males. They may be less likely to be taken under the wing of a professor or to be chosen for undergraduate research assignments. The engineering curriculum may be so intense in a four-year program that students have little opportunity to take classes outside engineering; this may alienate some students who want more diverse offerings. Finally, five-year programs pose special financial burdens on low-income students.

4. What Works at the State and Local Level

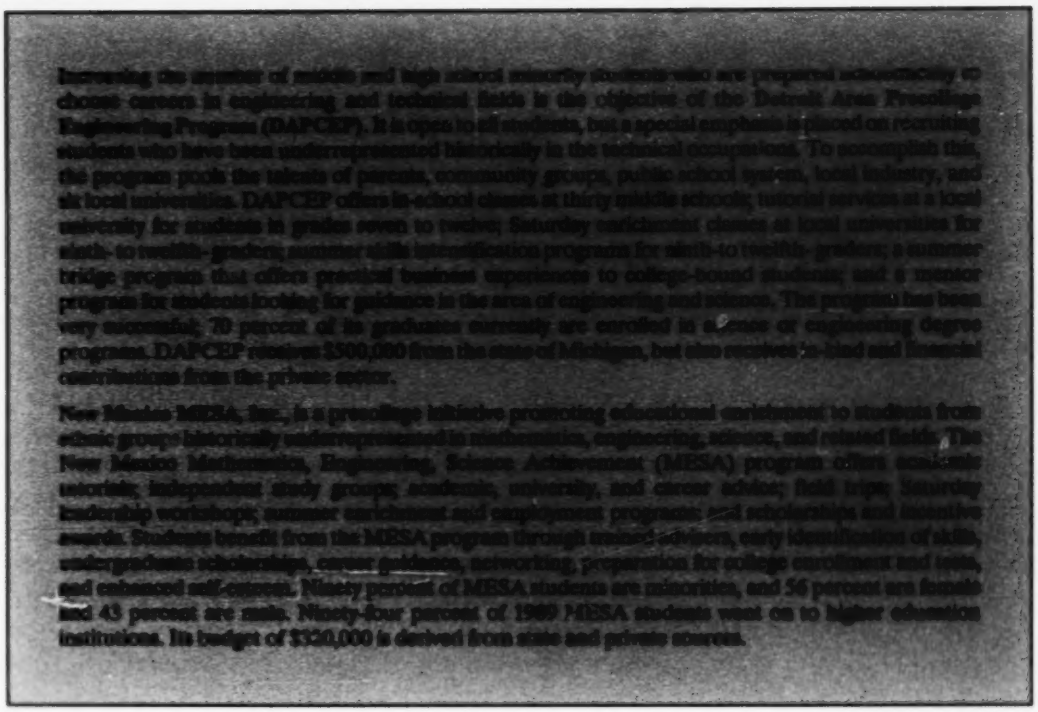
With a commitment from government, education, industry, and society, most of the barriers confronting female and minority engineering students can be removed. Intervention programs aimed at females and underrepresented minorities must be started as early as elementary or junior high school, and extend through the freshman year of college and into the engineering college and the wider campus environment. The program elements that help youngsters and college students to succeed are known, but intervention strategies must be comprehensive and interrelated to be effective. For example, encouraging students to enroll in advanced mathematics and science classes for which they have not been prepared may be self-defeating. Giving minority college students academic assistance without addressing social or emotional needs may be insufficient to keep students in the program.

What Works—Precollegiate

In a study of 168 early intervention programs for minority students, the American Association for the Advancement of Science found that "early, excellent, and sustained instruction" and assistance in mathematics and science leads to achievement for minority students equal to that of white male students.[52] Most experts agree that problems of low achievement must be attacked early, that parents must be involved, that positive role models are needed, and that supplementary activities such as Saturday schools or summer camps are useful components of a strategy to increase the number of students in the pipeline. The most effective programs have a strong academic focus.

A 1989 study by the Educational Testing Service (ETS) tracked the success of high-ability minority college students in mathematics, science, and engineering. It found that the students who persisted in their degree programs were more likely to have participated in math and science clubs in high school and were more likely to have taken advanced placement math and science courses and honors courses.[53]

Building a pool of potential mathematics, science, and engineering students ultimately may require elimination of school "tracking" practices that classify elementary and secondary students and place them in classes according to ability. Intensive pre-algebra courses for all students may increase the proportion of students who take Algebra I.

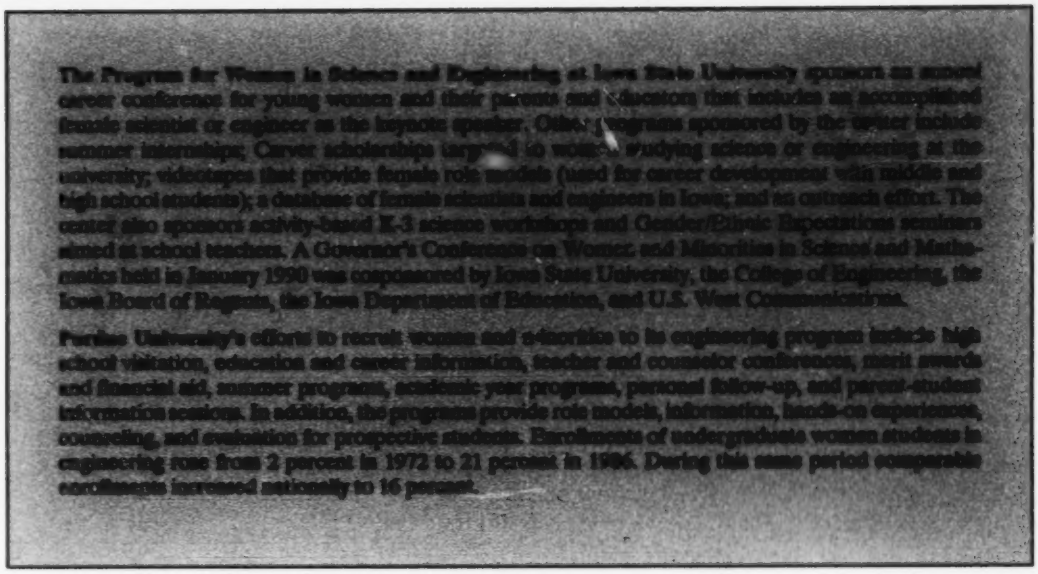


Increasing the number of middle and high school minority students who are prepared academically to choose careers in engineering and technical fields is the objective of the Detroit Area Precollege Engineering Program (DAPCEP). It is open to all students, but a special emphasis is placed on recruiting students who have been underrepresented historically in the technical occupations. To accomplish this, the program pools the talents of parents, community groups, public school system, local industry, and six local universities. DAPCEP offers in-school classes at thirty middle schools; tutorial services at a local university for students in grades seven to twelve; Saturday enrichment classes at local universities for sixth- to twelfth-graders; summer skills intensification programs for ninth-to twelfth-graders; a summer bridge program that offers practical business experiences to college-bound students; and a mentor program for students looking for guidance in the area of engineering and science. The program has been very successful; 70 percent of its graduates currently are enrolled in a science or engineering degree programs. DAPCEP receives $500,000 from the state of Michigan, but also receives in-kind and financial contributions from the private sector.

New Mexico MESA, Inc., is a precollege initiative promoting educational enrichment to students from ethnic groups historically underrepresented in mathematics, engineering, science, and related fields. The New Mexico Mathematics, Engineering, Science Achievement (MESA) program offers academic tutorials; independent study groups; academic, university, and career advice; field trips; Saturday leadership workshops; summer enrichment and employment programs; and scholarships and incentive awards. Students benefit from the MESA program through trained advisers, early identification of skills, undergraduate scholarships, career guidance, networking, preparation for college enrollment and tests, and enhanced self-esteem. Ninety percent of MESA students are minorities, and 56 percent are female and 43 percent are male. Ninety-four percent of 1989 MESA students went on to higher education institutions. Its budget of $320,000 is derived from state and private sources.

What Works—Recruitment

Precollegiate programs are a form of recruitment that begins early. However, programs also may target minorities and women in the eleventh and twelfth grades. Outreach programs may include a number of activities, including inviting students to campus and the engineering college for special visits, holding special summer sessions on campus, and having engineering faculty visit high schools. Contact with key individuals—high school counselors, teachers, and parents—is imperative. Yet a recent survey of engineering deans, Society of Women Engineers advisers, and women in engineering program administrators found that less than half of the engineering colleges had outreach programs to teachers and counselors.[54] An active recruiting program also may need to target able students who decide not to go to college or who choose to attend community colleges. Keeping in contact with these students, inviting them to campus engineering events, providing student mentors, and offering other follow-up activities may encourage them to ultimately enroll in an engineering program. The 1989 ETS study of high-ability students found that most students who enrolled in college mathematics, science, or engineering majors were influenced by college recruitment programs in those fields.

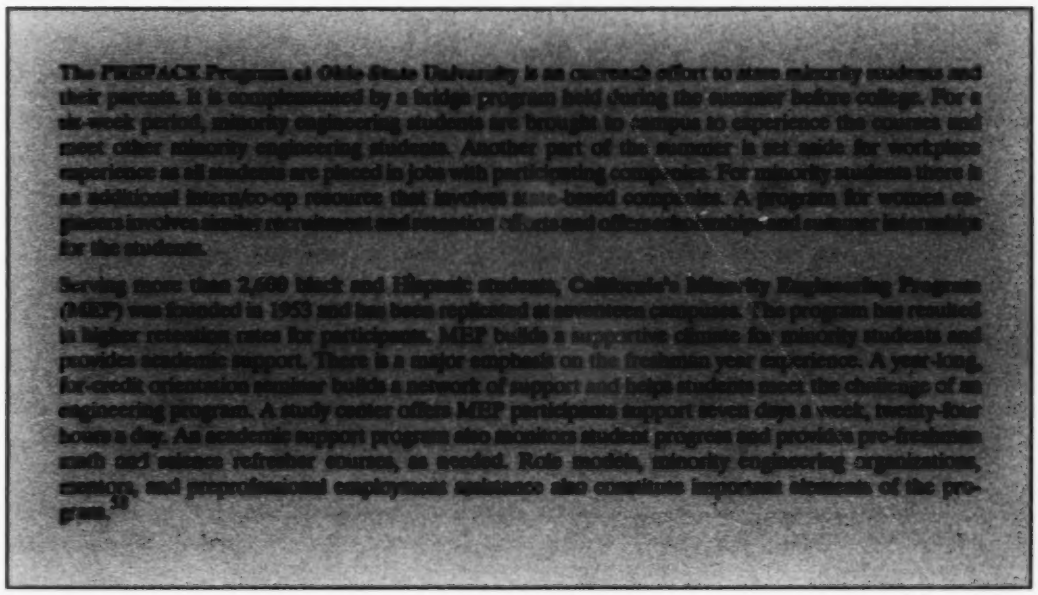


The Program for Women in Science and Engineering at Iowa State University sponsors an annual career conference for young women and their parents and educators that includes an accomplished female scientist or engineer as the keynote speaker. Other programs sponsored by the center include summer internships; Career scholarships targeted to women studying science or engineering at the university; videotapes that provide female role models (used for career development with middle and high school students); a database of female scientists and engineers in Iowa; and an outreach effort. The center also sponsors activity-based K-3 science workshops and Gender/Ethnic Expositions seminars aimed at school teachers. A Governor's Conference on Women and Minorities in Science and Mathematics held in January 1990 was cosponsored by Iowa State University, the College of Engineering, the Iowa Board of Regents, the Iowa Department of Education, and U.S. West Communications.

Purdue University's efforts to recruit women and minorities to its engineering program include high school visitation, education and career information, teacher and counselor conferences, merit awards and financial aid, summer programs, academic-year programs, personal follow-up, and parent-student information sessions. In addition, the programs provide role models, information, hands-on experiences, counseling, and evaluation for prospective students. Enrollments of undergraduate women students in engineering rose from 2 percent in 1972 to 21 percent in 1986. During this same period comparable enrollments increased nationally to 16 percent.

What Works—Campus Support

Whether they are provided the summer prior to the freshman year or before, early campus experiences are an important way to ease the transition from high school to college, or from a community college to a four-year institution. A variety of strategies have proven successful in helping students academically. Summer programs can help students who need remediation or greater confidence in their mathematics and science performance. During the first semester and beyond, providing special tutoring, establishing study groups, clustering female or minority students in classes to encourage academic and social interaction, and using the best teachers to teach freshman classes are effective academic support strategies. Several strategies may be used concurrently.



The PREFACE Program at Ohio State University is an outreach effort to area minority students and their parents. It is complemented by a bridge program held during the summer before college. For a six-week period, minority engineering students are brought to campus to experience the courses and meet other minority engineering students. Another part of the summer is set aside for workplace experience as all students are placed in jobs with participating companies. For minority students there is an additional intern/co-op resource that involves state-based companies. A program for women engineers involves similar recruitment and retention efforts and offers scholarships and summer internships for the students.

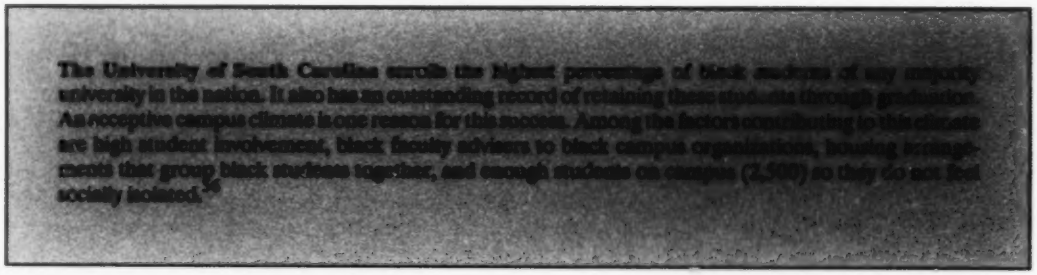
Serving more than 2,600 black and Hispanic students, California's Minority Engineering Program (MEP) was founded in 1953 and has been replicated at seventeen campuses. The program has resulted in higher retention rates for participants. MEP builds a supportive climate for minority students and provides academic support. There is a major emphasis on the freshman year experience. A year-long, for-credit orientation seminar builds a network of support and helps students meet the challenge of an engineering program. A study center offers MEP participants support seven days a week, twenty-four hours a day. An academic support program also monitors student progress and provides pre-freshman math and science refresher courses, as needed. Role models, minority engineering organizations, mentors, and preprofessional employment assistance also constitute important elements of the program.[38]

What Works—Within the Engineering College

Female and underrepresented minority students need special attention and support to avoid becoming isolated and discouraged in their engineering studies. Two kinds of help may be needed at this stage in the students' career: academic support for the underprepared students and emotional and moral support for all underrepresented groups to help overcome the isolation and stigma of majoring in a nontraditional discipline. Dr. Suzanne Brainard, director of the Women in Engineering program at the University of Washington, contends that the following conditions are necessary for a successful program for women or minorities within an engineering college: support and commitment from the engineering dean; a full-time director; an adequate budget; faculty commitment and involvement; student involvement in designing the program; and a system of accountability.[55]

Building self-confidence, linking faculty with students, providing upper-class mentors, bringing in female or minority graduates as role models, promoting collaborative study habits for students, and networking students are among the strategies that have been developed to encourage students to remain in engineering programs.[57] The goal of these efforts is student persistence. Interestingly, only 36 percent of colleges of engineering report special retention programs targeted to women in engineering.

The National Association of Minority in Engineering Program Administrators (NAMEPA) and the newly formed Women in Engineering Program Administrators Network (WEPAN) serve as mecnanisms to allow college-based minority engineering programs and women in engineering programs to share information and learn from each other.


The University of South Carolina enrolls the highest percentage of black students of any majority university in the nation. It also has an outstanding record of retaining these students through graduation. An accepting campus climate is one reason for this success. Among the factors contributing to this climate are high student involvement, black faculty advisers to black campus organizations, housing arrangements that group black students together, and enough students on campus (2,500) so they do not feel socially isolated.[56]

5. The Governor's Role

Over the past five years, the nation's Governors have waged an aggressive campaign to improve the nation's education system. In February 1990 they adopted a set of national education goals that includes the goal of being first in the world in math and science achievement by the year 2000. Within their own states, Governors have promoted programs to require additional teacher training in basic science and mathematics, and have established highly competitive scientific secondary schools. They also have stressed more performance measurement, greater accountability, and more parental choice.

State governments and state institutions have undertaken a variety of initiatives to increase the number of minority students preparing for and receiving degrees in engineering or pursuing science- and math-related careers. Some of these programs specifically target engineering, while others are directed at increasing the number of minorities who attend colleges or improving the math and science preparation of women and/or minorities. Many of the states have established initiatives to attract more minority teachers and to upgrade the math and science skills of elementary and secondary school teachers. Special scholarship funds and special incentive funds for colleges that support the recruitment of women and minorities into science and engineering have been established. Examples of state-supported initiatives are provided in Appendix A. Notwithstanding these initiatives, much remains to be done.

Governors can play a leadership role in encouraging the participation of women and minorities not only in engineering, but also in scientific and technical fields generally. Specifically, Governors can:

- Support education reform aimed at improving K-12 math and science education for all students.
- Provide programs targeted to women and underrepresented minorities.
- Work with the private sector to promote increased awareness among parents, teachers, counselors, and students of opportunities in math and science and of the importance of math and science to the future competitiveness of U.S. businesses.
- Serve as advocates for the establishment and expansion of programs that encourage more women and minorities to pursue careers in science and engineering.
- Encourage colleges of engineering to implement minorities and women in engineering programs through funding decisions and incentives. The elements that help students succeed are known. Colleges and universities

should be held accountable for creating a campus environment that recognizes and addresses the special needs of women and minority engineering students.

- Provide incentives to engineering schools that reward faculty for activities enhancing the educational experience of women and minority students.
- Form statewide cooperative efforts to link organizations and individuals involved in efforts to increase the numbers of women and minorities who receive the education, encouragement, and financial support they need to pursue a career in science or engineering.
- Incorporate human resource development goals into state science and technology programs. State governments have undertaken a variety of programs to support the development and application of new technologies. While the primary objective of these programs is to promote economic growth and development, such efforts provide opportunities for women and minority students to obtain valuable research experience. Governors can incorporate into their research and development programs the objective of increasing the involvement of women and minorities in science and engineering.

6. State Action Agenda

State agencies and state education institutions can take action at the precollege, undergraduate, and graduate levels to make students aware of opportunities in science and engineering, to prepare women and minorities to pursue advanced engineering degrees, and to improve graduation rates for women and minorities in engineering. A successful intervention strategy should incorporate the following objectives.

Improve the study of mathematics and science in grades K-12 for all students, and provide programs targeted to women and underrepresented minorities. Any effort to increase the number of students entering engineering programs will depend on the ability of the public school system to provide students with a strong foundation in basic mathematics and science. States should:

- Improve math and science teaching at the elementary and secondary levels by creating incentives to attract teachers to these subject areas, strengthening teacher preparation in both content and practical experience, and offering continuing professional development and support.
- Support programs designed to interest young women and minorities in math, science, and engineering, and to prepare them to enter college.
- Eliminate the tracking of students by ability to ensure that all students are taught advanced math and science skills.
- Allow alternative certification to enable practicing or retired scientists and engineers to teach math and science at the K-12 level.
- Provide incentives to promote collaboration among elementary and secondary schools and engineering, mathematics, and science faculty.

Improve the ability of students to transfer from two-year community colleges to engineering programs. About half of the women and minority students enrolled in college attend community colleges. If underrepresented groups are to be recruited or prepared to enroll in colleges of engineering, steps must be taken to facilitate the flow of students from community colleges to such colleges. To achieve this goal states should:

- Promote strengthened articulation (i.e., coordination of educational institutions to ensure that students are able to transfer credits) between two-year and four-year schools by developing transfer agreements and dual admission programs.

- Establish a statewide articulation coordinating committee to encourage programmatic articulation, monitor agreements, and adjudicate conflicts.
- Encourage colleges and universities to appoint articulation officers or liaison persons to help recruit students from community colleges and to help alleviate adjustment problems of transfer students.
- Create incentives for universities to work with community colleges and/or public four-year colleges with large minority enrollments through exchange programs, campus visitations, and orientation programs for transfer students.
- Encourage community colleges to strengthen their math and science programs to be more compatible with four-year schools.

Promote the development of undergraduate minority engineering programs to improve the academic performance and graduation rates of minority engineering students. Of the 270 universities in the United States with accredited undergraduate engineering programs, it is estimated that fewer than 100 have established programs to improve the academic performance and retention of minority students. These programs differ in level of effort and effectiveness. Much is known about the elements of programs that help students succeed. States should:

- Create challenge or incentive grants to encourage colleges of engineering and departments of mathematics and the sciences to develop recruitment and retention programs.
- Reward effective programs and encourage their replication.
- Encourage colleges of engineering and departments of mathematics and the sciences to engage in partnerships with the private sector. Seed money or incentives may be needed to initiate such efforts.
- Provide increased financial aid to minority engineering students so they will not be required to work excessively and can devote their full-time effort to engineering study.

Encourage the establishment and expansion of programs that specifically encourage more women to pursue careers in engineering. Women comprise about half of the population of every state in the nation. They are the most underrepresented, but also the most accessible, human resource available to meet the projected shortages of engineering talent for the future. To better utilize this resource, states should:

- Initiate or increase financial support to existing women in engineering programs at state colleges and universities and offer incentives to industries to support these programs.
- Reward effective programs and encourage their replication.
- Develop a state scholarship program to encourage young women to choose engineering as a major.
- Encourage state colleges and universities to use multiple admission criteria in addition to standardized test scores. The use of standardized test scores,

especially math scores, eliminates large numbers of women from the pool of potential engineering students.

Develop programs to improve faculty awareness of the needs of women and minority students at both the college and precollege level. Faculty have a key role to play in increasing the number and proportion of women and minority engineering students. Engineering faculty, the vast majority of whom are white males and increasingly foreign-born, may not be sensitive to the problems experienced by women and minority students. States should:

- Provide funding to train engineering faculty to be effective in their roles as academic advisers, mentors, and teachers of women and minority students, and to have higher expectations of these students.
- Support statewide implementation of programs aimed at educational equity, including training to help elementary and secondary teachers understand the cultural and sex-biased expectations they bring to the classroom.
- Provide incentives for universities to reward faculty for activities, such as mentoring and advising, that enhance the educational experience of women and minority students.
- Provide incentives for engineering schools to increase the representation of minorities on their faculty.
- Fund a program to support substantial loans to resident women and minority graduate students to pursue doctoral degrees in the sciences and engineering, with a forgiveness clause for faculty service at an in-state institution.

Hold schools and colleges and universities accountable for increasing the number of women and minority students who complete engineering degrees. In their efforts to encourage widespread application of proven approaches, states should:

- Collect enrollment and graduation data on groups of students who are involved in precollege or undergraduate programs as well as for all students. This information can be used to help inform policy and to identify effective intervention approaches.
- Encourage the Accreditation Board of Engineering and Technology to consider a college's success in enrolling and graduating women and minorities when the agency grants college of engineering accreditation.

Incorporate the goal of increasing the number of women and minority engineers into state science and technology programs. States have built an impressive track record in technology development and commercialization. State support for applied research and the establishment of advanced technology centers is encouraging more market-driven research and influencing university researchers. Such programs provide opportunities for student participation. States should:

- Require state-funded advanced technology centers or centers of excellence to incorporate activities in support of women and minority engineering students.

- Provide incentives to encourage the participation of women and minorities in state-funded research projects.
- Include women and minorities on public/private boards established to oversee state science and technology policy.

7. Conclusion

The current lack of women and minorities in science and engineering is a critical issue facing the nation. Since the 1970s policies and programs have been established to recruit and retain women and minorities in engineering degree programs. While a number of programs have proven highly successful, these efforts have been fragmented and implementation has not been widespread.

Changes are needed at the K-12 level to ensure that all students receive high quality instruction in math and science. The current emphasis on improving math and science education provides an opportunity to incorporate into proposed education reform the goal of improving the participation of women and minorities. Governors have actively supported education reform. Addressing the special needs of women and minorities should be included in any strategy to achieve the goal of being first in the world in math and science achievement by the year 2000.

Although efforts to improve K-12 science and math education are necessary, this approach will not be sufficient. Universities must do a better job of retaining and graduating women and minority engineering students. Of those students who enter college well prepared in math and science, women and minorities are less likely to complete their degrees. Currently, only one in three minority students who begin the study of engineering ever graduates. Engineering colleges must recognize the specific needs of minorities and women and take steps to change the white-male-dominated culture that exists on most campuses. Engineering faculty and administrators should be held accountable for policies and attitudes that discourage women and minority students.

Governors can play a key leadership role in increasing awareness of the critical need to enable more women and minorities to pursue technical degrees. However, they will want to work in conjunction with school systems, colleges and universities, and the private sector. Working together, it will be possible to ensure that all students receive the education needed to meet the demands of the twenty-first century.

Appendix A

State Initiatives

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State Initiatives

In summer 1989 the National Governors' Association conducted its annual survey of state education initiatives. The survey asked whether the state had policies or programs aimed at increasing the number of women and minorities obtaining engineering degrees. It also queried the states on programs or policies at the elementary or secondary level to improve the performance and/or increase the participation of female and minority students in math or science or to encourage their preparation for careers in engineering, math, or science.

The survey data were supplemented by follow-up phone calls. Some of the identified programs specifically target engineering, while others focus on increasing the number of minorities who attend colleges, or on improving the math and science preparation of women and/or minorities. Descriptions of these initiatives follow.

Reforming K-12 Math and Science Education

Numerous efforts are underway to revitalize and improve student preparation in mathematics and science. Over the next five years, the National Science Foundation is funding systemic statewide initiatives in science, mathematics, and engineering education in five to eight states. The National Science Teachers' Association and the American Association for the Advancement of Science are undertaking a joint project to effect large-scale changes in science education.

States also are actively assessing the quality of math and science instruction at the K-12 level and are taking steps to improve the curriculums and teacher preparation. Florida and Texas have developed comprehensive plans to improve precollege math and science education. A new college of science and technology is being established in Virginia.

Florida's Comprehensive Plan on Improving Mathematics, Science, and Computer Education was completed in April 1989. A joint effort among key government and business leaders, the plan provides recommendations on how to make Florida a world leader in mathematics, science, and computer education by the year 1999. Potential strategies include providing incentive funding for education for special interest students, adopting alternatives to tracking students by ability, developing programs to overcome stereotypes and biases, implementing targeted enrichment programs, encouraging active parental involvement, and expanding advanced placement and financial aid programs targeted to female, minority, at-risk, disabled, and gifted students.

Texas has plans to restructure science education in the core years of grades seven to ten. The restructuring is intended to provide science instruction enabling all students to acquire scientific literacy, to provide for advanced science preparation for a greater number of students, and to provide science teachers with additional skills and materials to the program's implementation. Pending approval by the Texas State Board of Education, the program could be phased in beginning in 1993 or 1994 and end in 1997 or 1998.

A new college of science and technology is being established at James Madison University in **Virginia**. Recruitment and program design efforts will focus on women and minorities. The goal is to establish a curriculum that will include courses on environmental data elements and operations research (computers and math) as well as a capstone senior science and technology course. The new college will be interdisciplinary in design and will focus on a teamwork approach.

Improving K-12 Math and Science Instruction

States are providing assistance to teachers in the development of new teaching methods and curriculums. In Michigan and New Jersey, centers have been established to provide support to both students and teachers at the elementary and secondary levels. Kentucky has established a loan program to enable existing teachers to obtain certification in math or science, and Virginia is training retired engineers and scientists to teach math and science.

In 1978 the Governor initiated the **Michigan** Math and Science Challenge Grant Program. The program awards funds on a competitive basis to establish math and science centers. The centers serve as resources for student enrichment and teacher programs related to the overall improvement of math and science education for students in grades K-12. Activities include teacher training, curriculum development, enrichment, and tutoring. All centers are required to develop a support network for the underrepresented.

The **New Jersey** Institute of Technology (NJIT), in conjunction with corporate leaders, established the Center for Pre-College Programs in 1978. The center provides a variety of programs for more than 1,000 secondary and elementary students and teachers each year. Funded by corporations, private foundations, and state and federal agencies, the programs have focused on subject matter content, development and modification of curriculum materials for classrooms, and strategies and approaches for classroom implementation. One of the projects is a collaborative effort between NJIT and Fairleigh Dickinson University. A model has been established for the professional development of junior high/middle school science teachers and their science curriculum. It includes a regional electronic resource-sharing network that actively involves teachers in exchanging and integrating successful approaches, materials, and curricular goals into their teaching practices.

Kentucky's Math and Science Incentive Loan Program encourages undergraduates, graduates, and existing teachers to obtain teacher certification in math or science. For undergraduate students, up to three years of educational loans can be made. Although the loan program is not specifically targeted to minorities, schools are encouraged to be aware of minorities' needs. Loans to students are forgiven on a prorated one-to-one basis—one year of loans forgiven for each year of teaching. Since 1982, 876 students have received loans totaling $2.8 million from the Kentucky Higher Education Assistance Authority.

At George Mason University in **Virginia**, a major corporation is helping train retiring engineers and chemists to teach mathematics and science. Sixteen retiring employees have enrolled in the one-year pilot program. At the end of the year the students will take the state teacher certification exam. The program also teams the

retirees with mentor teachers from the local school system to help facilitate their transition to teaching. The university plans to expand its program and to tap into corporate sources to fill shortages of math and science teachers.

Increasing Achievement Levels of Women and Minority Students in Math and Science

The most common intervention strategy at the precollege level is to improve the academic preparation and achievement of women and minority students. States are actively seeking to prepare minority students for college entry, to provide women and minorities with strong math and science skills, and to interest students in science and engineering careers.

The **Kentucky** Governor's Minority Student College Preparation Program exposes minority middle school and secondary students to the advantages of college enrollment and graduation. Activities include an early intervention program, minority teacher recruitment, college visitation, academic enhancement programs, and inter-institutional program coordination. The $250,000 program is funded by the Kentucky Council on Higher Education.

California's Mathematics, Engineering, and Science Achievement (MESA) program—a partnership of schools, colleges, businesses, and industries—began in 1970 at the University of California, Berkeley. MESA expanded to a statewide program in 1977. The state of California matches every private dollar raised by MESA with two state dollars, up to a specified limit. MESA works with students to promote higher achievement in high school and to encourage them to enroll in college-preparatory course work. Counseling, tutoring, and career development are important program components. To date, MESA has reached about 4,000 students, 90 percent of whom have gone to college. Sixty-six percent of MESA students major in science or engineering.

The state of **Washington** operates a similar MESA program designed to prepare underrepresented minority students to study math or science at the college level. Students are provided peer support through tutors, study groups, scholarships, field trips, and summer programs; parental support through advisory boards and family workshops; and school support from teachers and counselors. Begun in 1982, MESA is supported by the state, the National Science Foundation, school districts, universities, industry, engineering professionals, and parents.

Arizona, Colorado, Maryland, and **New Mexico** also have active MESA programs.

North Carolina's Mathematics and Science Education Network offers similar services. Operated by the University of North Carolina system, the network provides academic enrichment activities to 1,330 students from thirty-four junior/middle and senior high schools. In addition to student activities, the program involves parents, and provides teacher training workshops in mathematics, science, and communication skills.

Rhode Island's TIMES^2 (To Improve Math, Engineering, and Science Studies) is designed to increase the number of Rhode Island minority students preparing for

and receiving degrees in engineering, science, and math-related courses. Students are identified as early as sixth grade and are offered the opportunity to participate in the program. TIMES^2 supplements classroom instruction with field trips to industrial sites, museums, and educational institutions. Engineers, mathematicians, and scientists from a variety of disciplines serve as mentors and help students plan educational, career, and personal goals. Since its inception in 1979, the program has grown to include activities in ten schools and serves close to 400 students. TIMES^2 is a partnership program among business, industry, government, colleges and universities, and public school systems.

Delaware's Engineering and Applied Science Recruitment Fund supports programs similar to those of other states. To receive funding, programs must include professional volunteers or qualified staff, require parental involvement, coordinate with public schools' preparation programs, coordinate with postsecondary educational institutions, involve related organizations, initially involve students in grades seven to twelve, and provide professional leadership in educational activities for women and minority group members. The fund is supported by private contributions, state appropriations, and federal grants, with the state contribution not exceeding the private contributions from the previous year.

New York's Science and Technology Entry Program (STEP) provides support and special experiences for eligible students who are interested in science, technology, or other licensed professions. Designed for junior high school and high school students who are members of minority groups or who are economically disadvantaged, STEP prepares students for the formal training needed for work in these fields. Support can include assessment of knowledge and skills, special counseling, skills development, tutoring, mentoring, and paid field experience. The Collegiate Science and Technology Entry Program (CSTEP) provides similar support to college students.

While many programs generally prepare students to pursue careers in math and science, **Connecticut**'s Pre-Engineering Program, Inc. (CPEP) specifically prepares students for careers in engineering. Throughout junior and senior high school, CPEP provides strong enrichment to the public school curriculum so qualified students will be prepared to pursue university degrees in engineering, science, technology, mathematics, or teaching. The program works with students as early as the sixth grade, and provides action-oriented activities in practical science and mathematics. It is maintained by a network of specially trained teachers, local and site coordinators, and a parent group at each school. Begun in 1986 by the Science Museum of Connecticut, CPEP is a collaborative effort that depends on cooperation and support from private, public, nonprofit, and governmental sources.

Located in twenty cities, the **Texas** Alliance for Minorities in Engineering (TAME) is a program designed to encourage, motivate, and recruit minority students into the field of engineering. TAME starts at the junior high level and provides mentoring, role modeling, and summer jobs for participating students.

The Mid-American Consortium for Engineering and Scholastic Achievement (MACESA) involves six universities in **Kansas, Missouri**, and **Nebraska** area public schools, and the private sector. The consortium sponsors a two-week summer program for students entering their senior year. Forty students participate annually in the

program, which rotates from state to state each year. Students apply for the program in the fall of their junior year and ultimately are tied in with a college of engineering in their state.

Disadvantaged youth at the junior high and middle school levels in Philadelphia, **Pennsylvania**, are targeted by the Philadelphia Regional Introduction for Minorities in Engineering (PRIME) program. It develops their interest in math, science, and engineering, and prepares them to enter college. Activities include counseling, parent and community outreach, curriculum development in local schools, school-year and special summer programs, a career resource center, student internships, academic program enrichment, science fairs, field trips, and other activities. PRIME is a nonprofit organization that is governed by a board of directors that establishes policy and implementation strategies. It represents the efforts of government, business, higher education, professional associations, and parent groups. Initial funding came from a foundation, but today funding is derived from foundation grants and membership fees.

Promoting Interest Among Young Women in Math and Science

A number of states have undertaken initiatives designed to interest young women in math and science. Such programs expose young women to the opportunities available in scientific and technical fields, offer support to counteract the social pressures that may discourage them from pursuing math- or science-related interests, and encourage them to strive for greater achievement in math and science.

In 1986 the **Vermont** Technical College (VTC) established a comprehensive mentoring program to encourage young women to study math and science and choose careers in technology. The Women in Technology Program arranges for female engineers, technicians, and scientists to speak to junior and senior high school students about careers in technology; sponsors visits by high school women to workplaces to learn firsthand about professional women and their daily work and careers; and arranges campus visitations. The VTC Summer Technology Camp brings junior high school women to the campus for a week of engineering classes that are taught by professional women engineers and technicians. The program's operating budget of $60,000 is from the state department of education and is augmented by in-kind assistance from industry.

In 1984 the **Ohio** Academy of Science (with funding from the state of Ohio) formed the Women in Science, Engineering, and Mathematics Consortium of Ohio (WISEMCO) to involve more female students in science and math. The program maintains a strong statewide support and coordination network of professional organizations, colleges and universities, businesses and industries, government agencies, and local public and private schools. Currently 160 institutions participate. Twelve regional career development programs with 377 female scientists have been conducted for 3,750 students in grades four to twelve throughout Ohio.

In addition, a publication called *EXEMPLARS: Women in Science, Engineering and Mathematics* introduces young women in grades seven to twelve to career mentors. *EXEMPLARS* profiles women in Ohio who can serve as mentors and role models, provide access to research laboratories in hospitals, industries, and univer-

sities, become tutors for students in specific subjects, give advice on the selection of courses, help with science research projects, and suggest possible careers in science, engineering, and mathematics. Students contact the *EXEMPLAR* directly by writing a brief letter of introduction and stating their specific need for information or advice.

Mississippi State University (MSU) recently began phase one of the three-phase Martha's Daughters—Engineering Role-Model Activities for Seventh and Eighth Grade Rural Young Women (MADERA) program. As part of the project, a videotape is being developed to demonstrate to students ways to apply math and science principles to engineering-type problems. A workshop will be held for math and science teachers in which female MSU engineering students will introduce instructional materials and the options of engineering as a career for women. Phase two will consist of a more intensive workshop, school visits by MSU engineering students, and attendance of district engineering fairs. The third phase will be an intensive summer program for one woman from each participating school district. The project is funded locally from outside sources through the MSU Development Foundation.

Providing Financial Assistance To Minority Students

Dramatic increases in the cost of college have made access to college difficult for many minority students. One way in which states have tried to address this issue is by providing financial assistance.

The **Iowa** Minority Academic Grants for Economic Success (IMAGES) is a key element of the state's college-bound program for minority students. The program assures that a limited income is not a barrier to pursuing secondary education by providing funds to universities for financial aid. The State Board of Regents appropriated $800,000 to the three state universities for the grants and administrative costs. The program provided financial aid to 273 undergraduate students in its first year. Each university also is developing college-bound programs to provide information and enrichment experience for minority students.

The University of **Tennessee** at Knoxville has operated a Minority Engineering Scholarship Program since 1973, awarding 624 scholarships and graduating 260 students. Major national companies provide funding to cover all scholarships, and the university covers administrative expenses. The forty-five national corporate sponsors also have a cooperative summer internship program for scholarship students. The Tennessee Technological University School of Engineering also provides special undergraduate and graduate scholarship funds to minority candidates. Although these funds are available to all engineering students, thirty-one of forty-eight awards were made to women or minorities in 1989.

Recruiting Women and Minority Engineering Students

Many universities operate outreach programs to recruit women and minorities into undergraduate engineering programs. Such programs usually are targeted to junior and senior high school students who have demonstrated high proficiency in math and

science. Activities include inviting students to visit campuses, holding special summer sessions on campus, and having engineering faculty visit high schools.

The Minority Introduction to Engineering Program at Southern **Illinois** University at Carbondale offers black and Hispanic students an opportunity to learn more about engineering as a profession and become familiar with the educational requirements of an engineering program. A one-week, on-campus program introduces students to college-level work in math, engineering, robotics, and computer graphics. The university also has a Women's Introduction to Engineering Program to attract academically talented female students to engineering. The program draws on the resources of volunteers from the professional community as well as the engineering faculty and current students.

The University of **Massachusetts**' Engineering Career Orientation program is targeted to junior and senior high school minority students who demonstrate high potential in math, science, and other related engineering classes. Its goal is to stimulate interest in all phases of engineering and related fields, provide hands-on experience in academic areas related to engineering, acquaint minority students with the rigor of an engineering curriculum, and motivate students to pursue a postsecondary degree.

In **Tennessee** the Memphis State University College of Engineering sponsors a special summer program targeted to minorities and females in grades ten to twelve to interest them in entering engineering fields. They receive an introduction to engineering, a survey of the various fields of specialization within engineering, and laboratory experience.

Supporting Undergraduate Women and Minority Engineering Programs

A variety of programs have been developed to encourage women and minority students to remain in engineering and to complete their degrees. The programs provide both academic support and emotional and moral support. Building a support network, promoting collaborative study, and linking faculty and students are common components of undergraduate retention programs.

The University of **Maryland** at College Park administers the Center for Minorities in Science and Engineering. The center provides a complete package of services designed to assist minority students from the time they first consider science or engineering as a major to the time they graduate. In addition to providing academic advising and tutorial services, the center provides students with professional mentors from business and industry. Its "Bridge" program assists freshmen considering science or engineering majors. The University of Maryland at College Park ranked twelfth in the nation in 1988 in the number of baccalaureate degrees in engineering awarded to blacks.

Established in 1988, the University of **Washington**'s Women in Engineering (WIE) program increases the participation of women in engineering at the graduate and undergraduate levels through increased recruitment and retention. WIE offers seminars, workshops, and forums as well as individual counseling services, study groups, and two support groups. A Big Sisters Program provides one-to-one support

for women in engineering and the Mentoring Program helps facilitate the personal and career development of women in engineering. An advisory board of professionals from the engineering profession, government, and industry provide counsel on programs, fund-raising, and program evaluation.

The **Pennsylvania** State University Minority Engineering Program (MEP) offers advising, counseling, and tutoring services through a minority engineering student assistance center. The program assists in the recruitment and retention of underrepresented minorities, and encourages qualified students to pursue engineering careers. MEP is run out of the dean's office, but gets assistance from an external advisory committee composed of representatives from the university, industry, and government. The program is complemented by a women in engineering program of a similar nature.

Texas A&M University's Minority Engineering Student Affairs Office is responsible for identifying, preparing, recruiting, and retaining minority students in science and engineering programs. With start-up funds from the Exxon Educational Foundation, the office developed the Minority Engineering and Geology Program (MEGP), a high school intervention program, and the South Texas Engineering, Mathematics, and Science program (STEMS), which seeks to address precollege science, math, and career education. The office and programs are funded by industry.

Recruiting Minority Students, Teachers, and Faculty

States are actively encouraging their schools, colleges, and universities to undertake special efforts to recruit minority students, teachers, and faculty.

The **Alabama** Commission on Higher Education has proposed a special funding program to encourage institutions of higher education to develop programs to recruit and graduate more minority students. The legislature will accept proposals from the state's two- and four-year institutions for underwriting the costs of these efforts. Under Alabama's Minority Access and Achievement Program seven higher education institutions have pledged $1 million over two years to train 200 minority teachers.

The **Wisconsin** State University System's Targeted Opportunities Program provides money to its universities to hire recognized scholars who are in an academic area in which there is a need for diversity. The funds also can be used to implement activities aimed at recruiting minority faculty. Funds can be used for visiting scholars, trips to and from the university for purposes of recruitment, and academic networking.

Higher education institutions in **New York** are receiving salary funding for three years as an incentive to hire underrepresented faculty. They provide the state with information on a particular candidate from an underrepresented group, and the state provides funding for the position. In the first year, thirty-five appointments were made. The second year of the program will include math and science teachers as a priority.

Appendix B

Women and Minorities in Engineering Project Advisory Committee

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Endnotes

1 The Task Force on Women, Minorities, and the Handicapped in Science and Technology, *Changing America: The New Face of Science and Engineering, Interim Report* (Washington, D.C.: U.S. Congress, 1988), p. 1.

2 Asian students are not included in the minority category because they are overrepresented in the sciences and in engineering compared with their proportion in the population at large. Asian students typically are as prepared to enter engineering programs as are white males, and they succeed at an even higher rate. Indeed, the graduation rate for Asian students in engineering programs is quite high, due to a very low dropout rate and the high number of Asian students who transfer into the field. However, it is recognized that not all Asian students are high achievers.

3 National Science Foundation, "Future Scarcities of Scientists and Engineers: Problems and Solutions—A Working Draft" (Washington, D.C.: National Science Foundation, 1989); Office of Technology Assessment, *Higher Education for Science and Engineering: A Background Paper* (Washington, D.C.: Office of Technology Assessment, 1989); Task Force on Women, Minorities, and the Handicapped in Science and Technology, *Changing America: The New Face of Science and Engineering, Final Report* (Washington, D.C.: U.S. Congress, 1989).

4 National Governors' Association, *America in Transition: Report of the Task Force on Research and Technology* (Washington, D.C.: National Governors' Association, 1989).

5 American Association of Engineering Societies, Engineering Manpower Commission, "Engineering Enrollment Highlights, Fall 1989," *The Engineering Manpower Bulletin*, no. 100 (April 1990). Data from the *Bulletin* show a 14 percent drop in the number of engineering degree recipients between 1985 and 1989. Nonetheless, at this time, Richard Ellis of AAES does not foresee a problem with the future supply of engineers.

6 Betty M. Vetter, "Demographics of the Engineering Student Pipeline," *Engineering Education*, vol. 78, no. 8 (May 1988), p. 735.

7 A.K. Finkbeiner, "Demographics or Market Forces?" *MOSAIC*, vol. 18, no. 1 (spring 1987), pp. 10-17.

8 James R. Mingle, *Focus on Minorities: Trends in Higher Education Participation and Success* (Denver, Colo.: Education Commission of the States and the State Higher Education Executive Officers, 1987), p. 1.

9 Vetter, p. 739.

10 Suzanne G. Brainard, "A National Agenda for the 21st Century: Women in Engineering," prepared for Radcliffe College, 1989, p. 6.

11 John Arundel, "Stagflation for Female Engineers," *The New York Times*, October 1, 1989, p. 32.

12 Jane Zimmer Daniels, "Increasing the Number of Women in Engineering: The Role of Governors," in *Realizing the Potential of Women and Minorities in Engineering: Four Perspectives from the Field* (Washington, D.C.: National Governors' Association, 1990).

13 The absolute number of black students has fluctuated during the decade, but has been rising since 1981 with declines experienced in 1983, 1985, and 1988. In 1988 752,000 black students between the ages of eighteen and twenty-four attended college compared with 748,000 in 1976. However, the proportion of black students in this age group attending college has declined. Hispanic student enrollment has climbed rather steadily upward, but has failed to keep pace with the burgeoning Hispanic population in this age group, thus suppressing the percentage of Hispanic eighteen- to twenty-four-year-olds enrolled in college. Absolute numbers of black and Hispanic eighteen- to twenty-four-year-olds who were enrolled in college between 1976 and 1988 can be derived from Table 2 in Deborah J. Carter and Reginald Wilson, *Minorities in Higher Education: Eighth Annual Status Report* (Washington, D.C.: American Council on Education, 1989), p. 23.

14 Carter and Wilson. The proportion of black eighteen- to twenty-four-year-olds ever enrolled in college (i.e., those who have attended college but who are no longer enrolled, as well as those who are currently enrolled) was slightly over 50 percent in 1976 and by 1988 was 46.6 percent. A similar trend is seen for Hispanics, though the fluctuations experienced between 1976 and 1988 are less dramatic than for blacks: the highest proportion of Hispanic eighteen- to twenty-four-year-olds ever enrolled in college was 48.9 percent in 1976, and the low was 43.2 percent in 1978. The comparable figure for 1988 was 47.1 percent.

15 American Council on Education and Education Commission of the States, *One Third of A Nation* (Washington, D.C.: American Council on Education, 1988), p. 11.

16 Peter Nulty, "The Hot Demand for New Scientists," *Fortune*, July 31, 1989, pp. 155-63.

17 National Action Council for Minorities in Engineering, Inc., *NACME News* (New York: National Action Council for Minorities in Engineering, Inc., September 1989).

18 Commission on Professionals in Science and Technology, *Professional Women and Minorities: A Manpower Data Resource Service*, 8th edition (Washington, D.C.: Commission on Professionals in Science and Technology, December 1989).

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20 Vetter, p. 738.

21 "Attitudes and Characteristics of This Year's Freshman," *The Chronicle of Higher Education*, January 24, 1990, p. A33; Office of Technology Assessment, p. 21.

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24 National Research Council, p. 61.

25 Jeannie Oakes, *Lost Talent: The Underparticipation of Women, Minorities, and Disabled Persons in Science* (Santa Monica, Calif.: The Rand Corporation, 1990), pp. 52-53.

26 "Defects Found in Preparation of Freshmen in Science and Math," *The Chronicle of Higher Education*, November 8, 1989, pp. A37, A39.

27 Office of Technology Assessment, p. 198.

28 Linda Darling-Hammond, presentation to the National Governors' Association Task Force on Education Staff Advisory Council, Washington, D.C., May 3, 1990.

29 Oakes, p. 42.

30 The Carnegie Foundation for the Advancement of Teaching, Board of Trustees, *An Imperiled Generation: Saving Urban Schools* (Princeton, N.J.: The Carnegie Foundation for the Advancement of Teaching, 1988), pp. 24-27.

31 Oakes, p. 53.

32 U.S. Department of Education, Office of Educational Research and Improvement, *Education Research Bulletin* (fall/winter 1989-90), p. 3.

33 Eleanor Baum, "Transfer Students in Engineering Education," *Engineering Education*, vol. 78, no. 8 (May 1988), pp. 769-71.

34 Baum, p. 770; and National Science Foundation, Division of Undergraduate Science, Engineering, and Mathematics Education, *Report on the National Science Foundation Workshop on Science, Engineering, and Mathematics Education in Two-Year Colleges* (Washington, D.C.: National Science Foundation, 1989).

35 Fred L. Pjincus and Alayne Archer, *Bridges to Opportunity: Are Community Colleges Meeting the Transfer Needs of Minority Students?* (New York: The College Board, 1989).

36 The Task Force on Women, Minorities, and the Handicapped in Science and Technology, p. 12.

37 National Science Foundation, Division of Undergraduate Science, Engineering, and Mathematics Education, *Workshop of Science, Engineering, and Mathematics Education*, p. 4.

38 National Science Foundation, "Future Scarcities of Scientists and Engineers," p. 21.

39 Engineering Manpower Commission, phone conversation, May 10, 1990.

40 Genevieve M. Ramirez and Paul B. Thayer, "Minority Students on Campus," in *A Crucial Agenda: Making Colleges and Universities Work Better for Minority Students*, edited by Morgan Odell and Jere J. Mock (Boulder, Colo.: Western Interstate Higher Education Commission, 1989).

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50 Eleanor Baum, "Why So Few Women in Engineering?" *Engineering Education*, vol. 79, no. 10 (July/August 1989), pp. 556-57.

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57 Vetter, p. 738, is one of the experts who have written about successful strategies.

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